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Technical Report

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BALLISTIC GRILLES

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Two experimental ballistic grilles were tested at U.S. Army Tank-Automotive Command airflow lab. The purpose of the test was to determine the airflow restriction of the two grilles and determine the effects on the Advanced Integrated Propulsion System cooling exhaust.

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1.0. INTRODUCTION

This report, prepared by the Propulsion Division, Tank-Automotive Technology Directorate, U.S. Army Tank-Automotive Command (TACOM), details a test performed on two experimental ballistic grilles (Code A and Code B) designed for the Armored Family of Vehicles (AFV) heavy, front engine chassis with an Advanced Integrated Propulsion System (AIPS) powerpack.

2.0. OBJECTIVE

The objective of the test was to determine the airflow restrictions of two experimental ballistic grilles and their effects on the AIPS cooling exhaust.

3.0. CONCLUSIONS

Of the two ballistic grilles tested, the code "B" grille offered the lowest airflow restrictions in both normal and reverse directions. The code "B" grille offered airflow restrictions that met the specifications required for the AIPS powerpack.

The velocity measurements with the pitot tube showed that the velocity distribution across the grilles' surface was uniform, except around the edges of the grille where the velocities varied by 300 to 600 feet per minute (fpm). The pitot tube values were only indicative of the airflow through the grilles and do not give accurate velocity readings due to large fluctuations of the readings.

4.0. RECOMMENDATIONS

Based on low restriction, the code "B" grille is recommended for the AFV vehicle with the AIPS powerpack, since this grille meets the specified requirements for that vehicle.

The code "A" grille is not recommended since the airflow restrictions of the grille do not meet AIPS requirements.

5.0. DISCUSSION

5.1. Test Equipment

The test equipment consisted of the following:

- Industrial fan, American Blower Company, Type PB, size 52, with control equipment, capacity: 10,000 cubic feet per minute (CFM) at 56 inches of water.
- Two sharp-edge orifice plates, 12-3/8-and 17-inch diameters.
- Test duct, 24-inch diameter, conforming to Air Moving and Conditioning Association requirements.
- Plenum chamber 6 feet by 6 feet by 8 feet.
- Inclined manometer, Meriam Instrument Company, 0 - 6 inches water range.
- Manometers (4) Meriam Instrument Company, 0 - 30 inches water range.
- Thermocouples (3).
- Sling psychrometer.
- Barometer.
- Pitot tube.

5.2. Test Material

The test material consisted of:

- Exhaust grille code "A" (Figures 5-1 thru 5-3)
- Exhaust grille code "B" (Figures 5-4 and 5-5)

5.3. Test Method

The test grille was mounted on top of a plenum chamber at TACOM's airflow lab (Building 7). All openings and gaps around the grilles' perimeter were plugged and sealed so that the air flowed through the ballistic portion only. Airflows through the grille were recorded for pressure drops of 1 to 5 inches of water in approximately 1-inch increments. The grilles were tested in normal and reverse flow. Instrumentation was installed to measure:

- Pressure differential (ΔP) across air flow orifice in inches of water.
- Static pressure before and after the orifice.
- Temperature of air upstream of the orifice.

Figure 5-1. Exhaust Grille Proposal 1, Code "A"

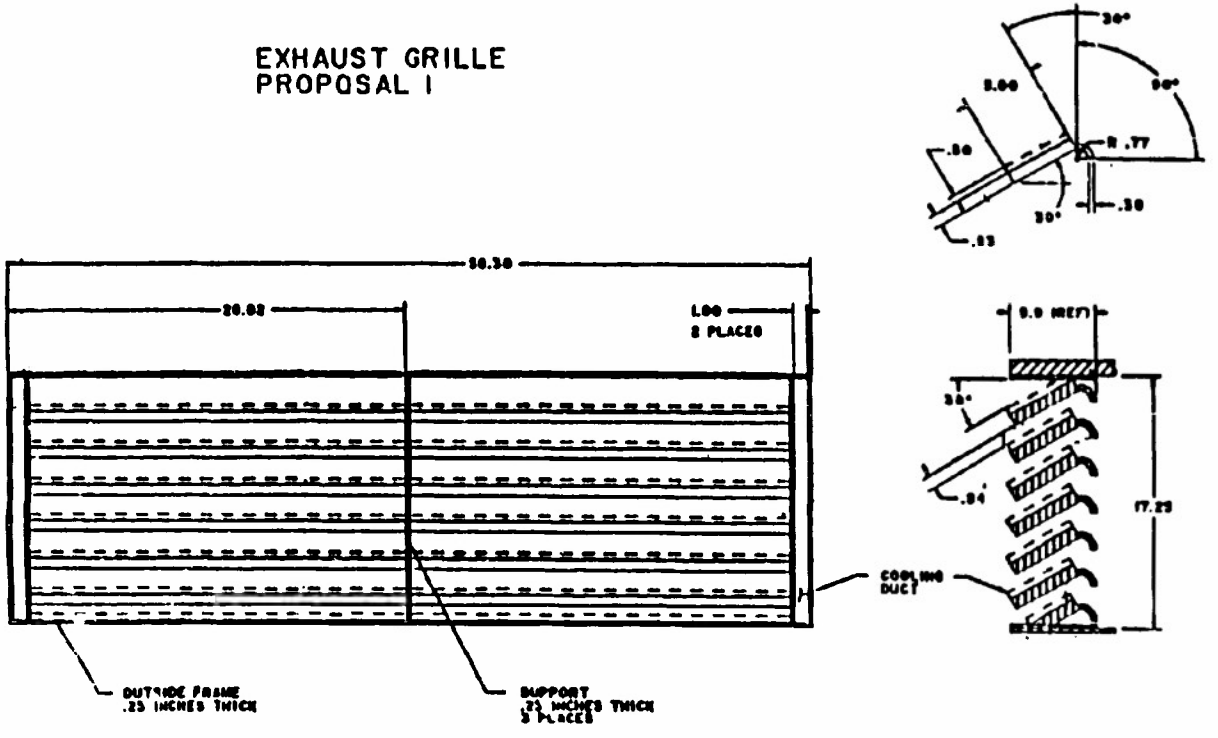


Figure 5-2. Side View of Grille Code "A"

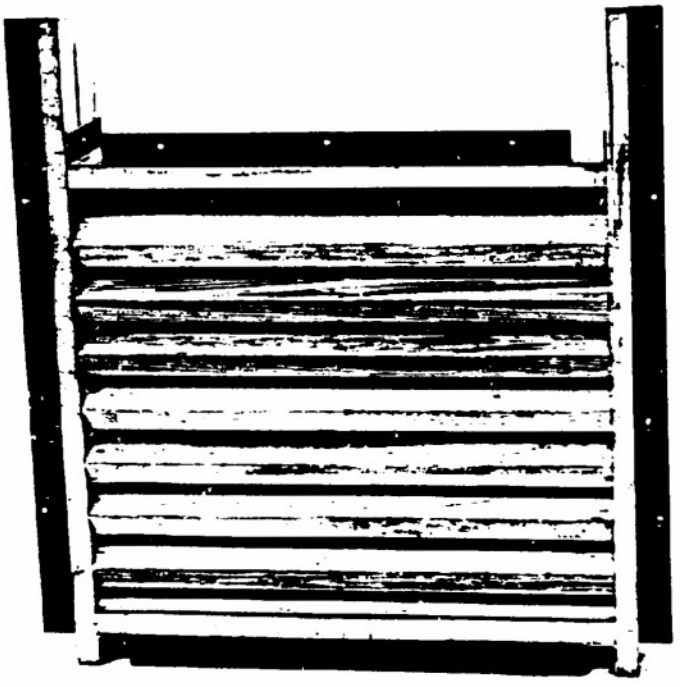
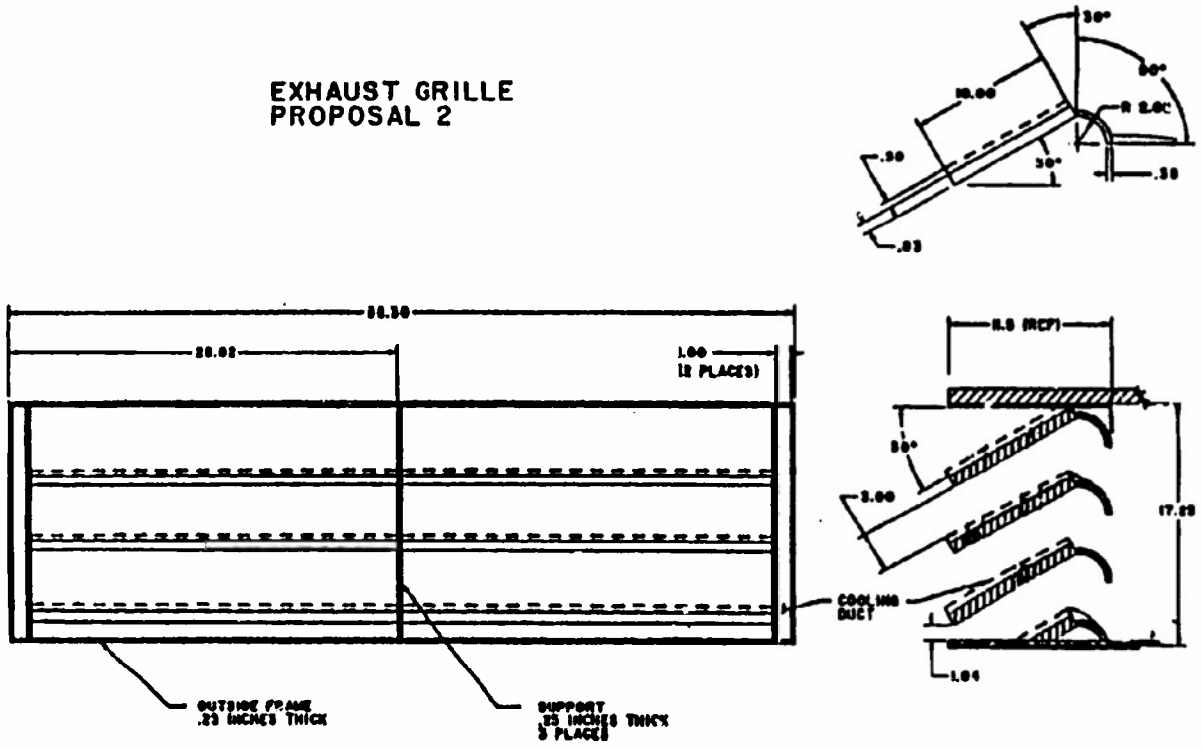


Figure 5-3. Front View of Grille Code "A"

Figure 5-4. Exhaust Grille Proposal 2, Code "B"



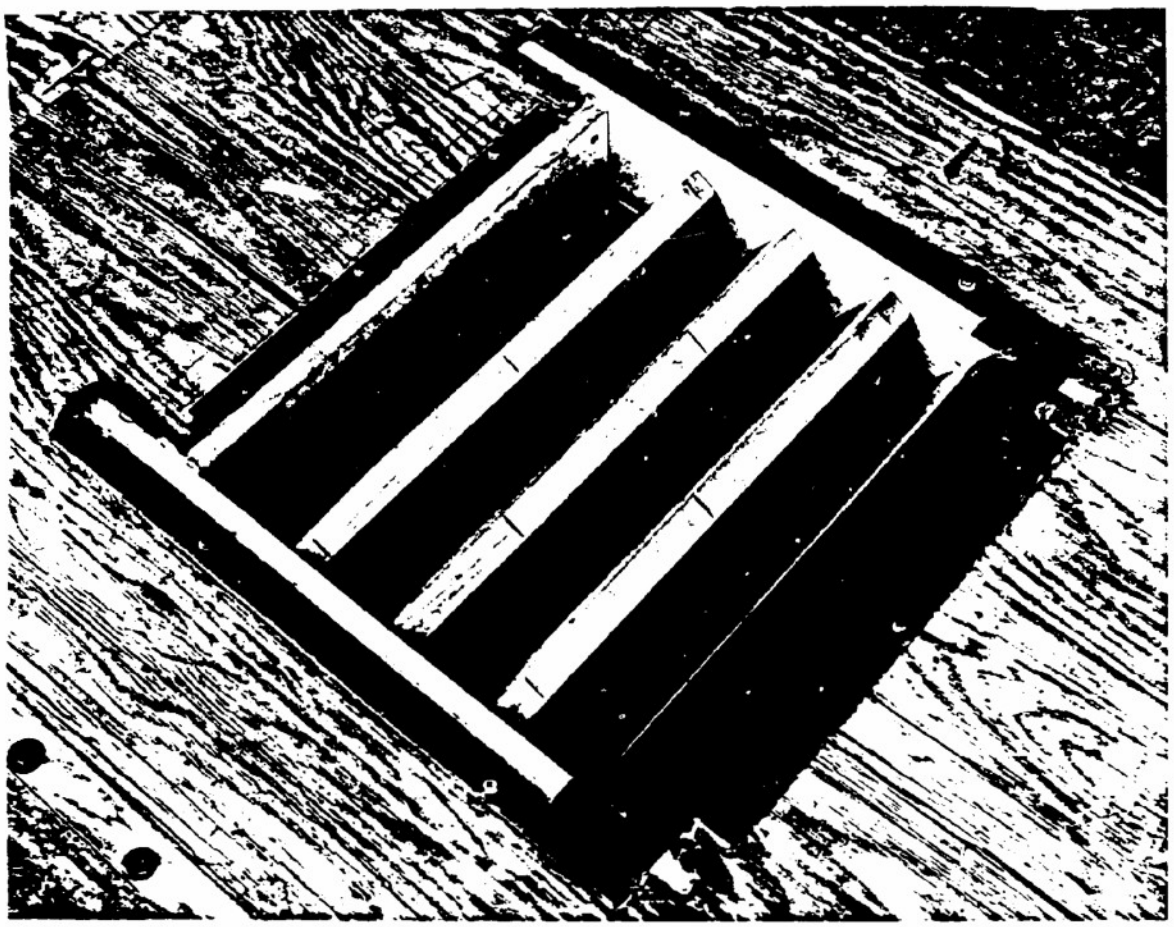


Figure 5-5. Front View of Grille Code "B"

- Pressure differential (ΔP) across the grille.

Ambient temperature in degrees Fahrenheit, grille temperature in degrees Fahrenheit, and barometric pressure in inches of Mercury were also recorded for each run.

The velocity of the air flowing in the normal direction of the grille was calculated using the formula:

$$V = \frac{1096.2 \times C \times A\sqrt{\Delta P/\rho}}{A \text{ eff}}$$

This velocity is smaller than the measured velocity on the other side of the grille, because the air flowing through the grille experiences a sudden reduction of area due to the louver restrictions.

5.4. Test Results

The air velocities were determined by direct measurement using a pitot tube. Velocities were determined by the following formula:

$$V = 1096.2\sqrt{\frac{Pv}{D}}$$

Pv = Velocity Pressure

D = Air Density (lbm/ft^3)

$D = 1.325 \times \frac{P_B}{T}$ (air being considered a perfect gas)

P_B = actual barometric reading (in. Hg)

T = ambient temperature reading (°R)

Air velocity was also calculated as mentioned earlier by the formula:

$$V = \frac{1096.2 \times C \times A\sqrt{\Delta P/\rho}}{A \text{ eff}}$$

A = Area of orifice (ft^2)

ΔP = Pressure across the orifice (in. H_2O)

C = Orifice coefficient

ρ = Air density corrected to .073 lbm/ft^3

A eff = Effective face area of the grille (ft^2)

The volumetric airflow (CFM) and the air velocity were determined from the following formula:

$$Q = 1096.2 \times A \times C\sqrt{\Delta P/\rho air}$$

$$V_f = \frac{Q}{A\ eff.}$$

V_f = Face velocity of air entering grille (fpm)

A eff. = Effective area of the grille (ft^2)

A = Area of orifice (ft^2)

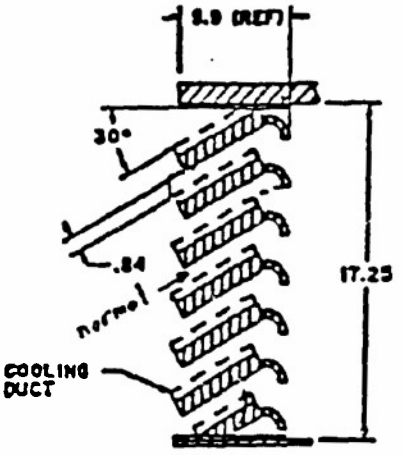
C = Orifice coefficient

ΔP = Pressure differential across the orifice (in. H_2O)

ρair = Corrected density of air before the orifice (lbm/ft^3)

Air velocities and the volumetric airflow of grilles Code "A" and Code "B" are shown in Tables 5-1 and 5-2. Air velocity was also checked at several points across the grilles as shown on Figure 5-6 and Figure 5-7, using a pitot tube. This velocity check was taken on top of the plenum chamber only. Thus, when the air was flowing in the normal direction the pitot tube reading was reading the face velocity exiting the grille and not the face velocity of the air entering the grille. Plots of face velocity vs. air restriction are shown in Figures 5-8 and 5-9.

Table 5-1. Velocity, Normal and Reverse Direction, Grille Code "A"



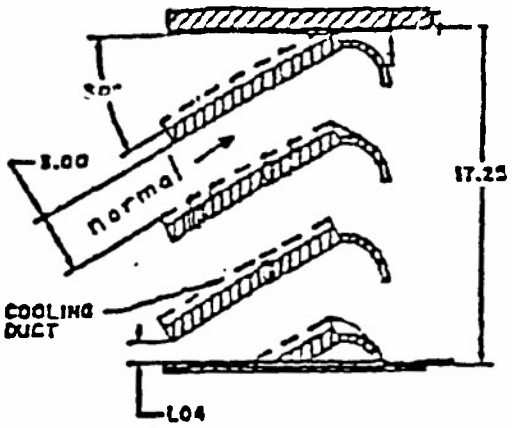
NORMAL DIRECTION

ΔP (Grille) (in. H_2O)	ρair (lbm/ft)	Q (CFM)	Vc (FPM)	ΔP orifice (in. H_2O)
1.00	0.075	2841.30	1219.44	1.67
2.00	0.075	3908.44	1677.44	3.16
3.00	0.075	4822.05	2069.55	4.81
4.00	0.074	5831.49	2502.79	1.60
5.00	0.074	6470.72	2777.13	1.97
7.85	0.074	8130.18	3489.35	3.11

REVERSE DIRECTION

ΔP (Grille) (in. H_2O)	ρair (lbm/ft)	Q (CFM)	Vc (FPM)	ΔP orifice (in. H_2O)
1.00	0.074	2746.13	1178.60	1.56
2.00	0.074	3757.08	1612.48	2.92
3.00	0.074	4638.09	1990.60	4.45
4.00	0.073	5454.86	2341.14	1.40
5.00	0.073	6116.12	2624.94	1.76
7.85	0.073	7755.56	3328.57	2.83

Table 5-2. Velocity, Normal and Reverse Direction, Grille Code "B"

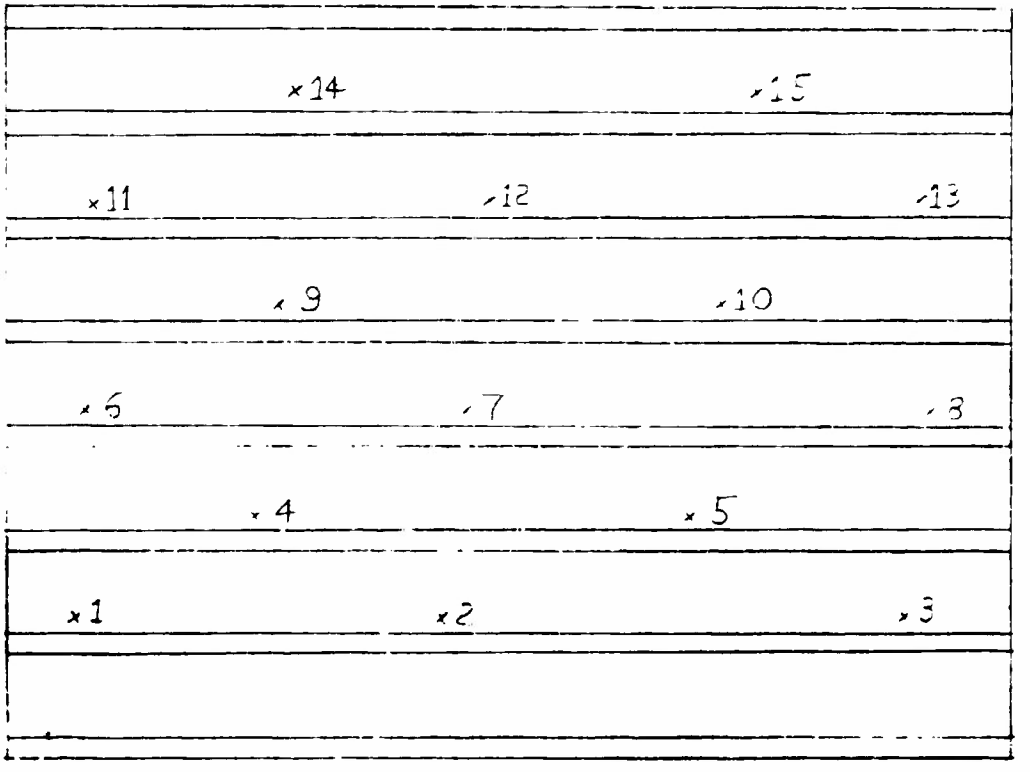


NORMAL DIRECTION

ΔP (Grille) (in. H_2O)	ρair (lbm/ft)	Q (CFM)	Vc (FPM)	ΔP orifice (in. H_2O)
0.44	0.074	2284.92	997.78	1.08
1.00	0.074	3659.23	1597.92	0.63
2.00	0.074	5092.13	2223.64	1.22
3.00	0.074	6354.72	2774.99	1.90
3.51	0.074	6869.04	2999.58	2.22
4.00	0.074	7230.82	3157.56	2.46
5.00	0.074	8143.24	3556.00	3.12

REVERSE DIRECTION

ΔP (Grille) (in. H_2O)	ρair (lbm/ft)	Q (CFM)	Vc (FPM)	ΔP orifice (in. H_2O)
1.00	0.074	3773.61	1647.87	0.67
2.00	0.074	5133.70	2241.79	1.24
3.00	0.074	6304.35	2752.99	1.87
3.33	0.074	6869.04	2999.58	2.22
4.00	0.074	7289.37	3183.13	2.50

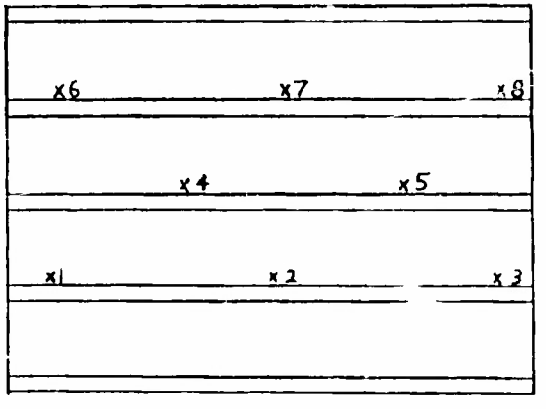


MEASURED VELOCITIES (FPM)
(NORMAL/REVERSE)

Location	1.0in. H_2O	2.0in. H_2O	3.0in. H_2O	4.0in. H_2O	5.0in. H_2O	7.85in. H_2O
1	3802/3175	5225/4032	6585/4939	7665/5754	8329/5754	10535/8034
2	3906/3251	5451/4417	6825/5410	7927/6560	8665/6928	10878/8820
3	4106/2764	5524/4092	6825/5258	7823/6034	8851/6433	11064/8436
4	4008/3469	5668/4324	6884/5410	7823/6433	8805/7163	11064/8630
5	4008/3350	5696/4598	7056/5703	8080/6560	9034/7391	11319/9277
6	3802/2851	5377/3607	6462/4417	7665/5130	8665/5896	10535/7719
7	4107/3374	5738/4685	7113/5702	8080/6560	9124/7611	11604/9541
8	4008/2794	5377/3607	6706/4508	7771/5145	8180/5608	11319/7047
9	4203/3469	5808/4633	7288/5558	8080/6303	9168/7163	11463/9366
10	4107/3374	5822/4771	7113/5631	8280/6560	9079/7611	12019/9366
11	3906/2419	5377/3276	6462/4132	7558/4639	8426/5305	10878/6170
12	4107/3515	5738/4856	7390/6115	8130/7163	9168/7931	11985/10130
13	4008/2351	5451/3124	7113/3718	7978/4267	8805/4814	11064/6170
14	4008/3561	5539/5101	6825/6247	7823/7163	8851/8436	11391/10917
15	3967/3561	5596/4939	7169/6115	7875/7163	9168/8436	11283/10687

Figure 5-6. Velocity Distribution, Grille Code "A"

Figure 5-7. Velocity Distribution, Grille Code "B"



MEASURED VELOCITIES (FPM)
(NORMAL/REVERSE)

Location	.44in. H_2O	1.0in. H_2O	2.0in. H_2O	3.0in. H_2O	3.33in. H_2O	3.51in H_2O	4.0in. H_2O	5.0in. H_2O
1	2209/----	3370/3144	4766/4628	5986/5086	----/5595	6304/----	6985/6156	7598/----
2	2613/----	3884/3630	5625/5134	6859/5741	----/6418	7372/----	7861/7147	8835/----
3	2209/----	3247/3144	4766/4257	5837/4803	----/5741	6042/----	6867/6545	7544/----
4	2551/----	3926/4159	5478/5595	6740/6913	----/7261	7205/----	7809/8515	8742/----
5	2582/----	3821/3851	5478/5882	6800/7374	----/7831	7317/----	7861/7913	8789/----
6	2017/----	3370/2870	4503/4159	5696/5134	----/5292	6042/----	6376/6156	6985/----
7	2614/----	3821/4257	5478/6223	6740/7485	----/7485	7317/----	7861/8800	8742/----
8	2281/----	3370/3010	4850/4803	5837/5292	----/5292	6368/----	6687/6545	7861/----

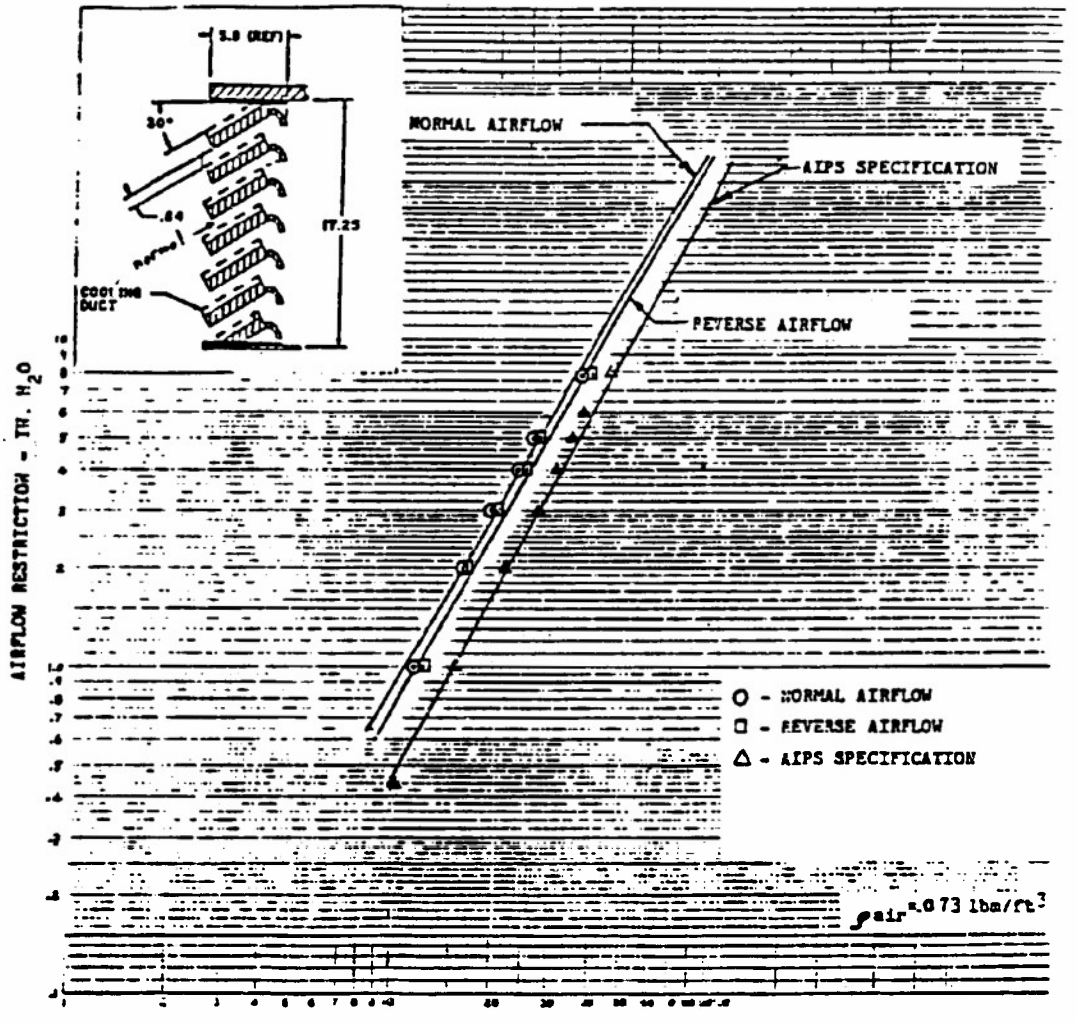


Figure 5-8. **Face Velocity vs. Airflow Restriction, Grille Code "A"**

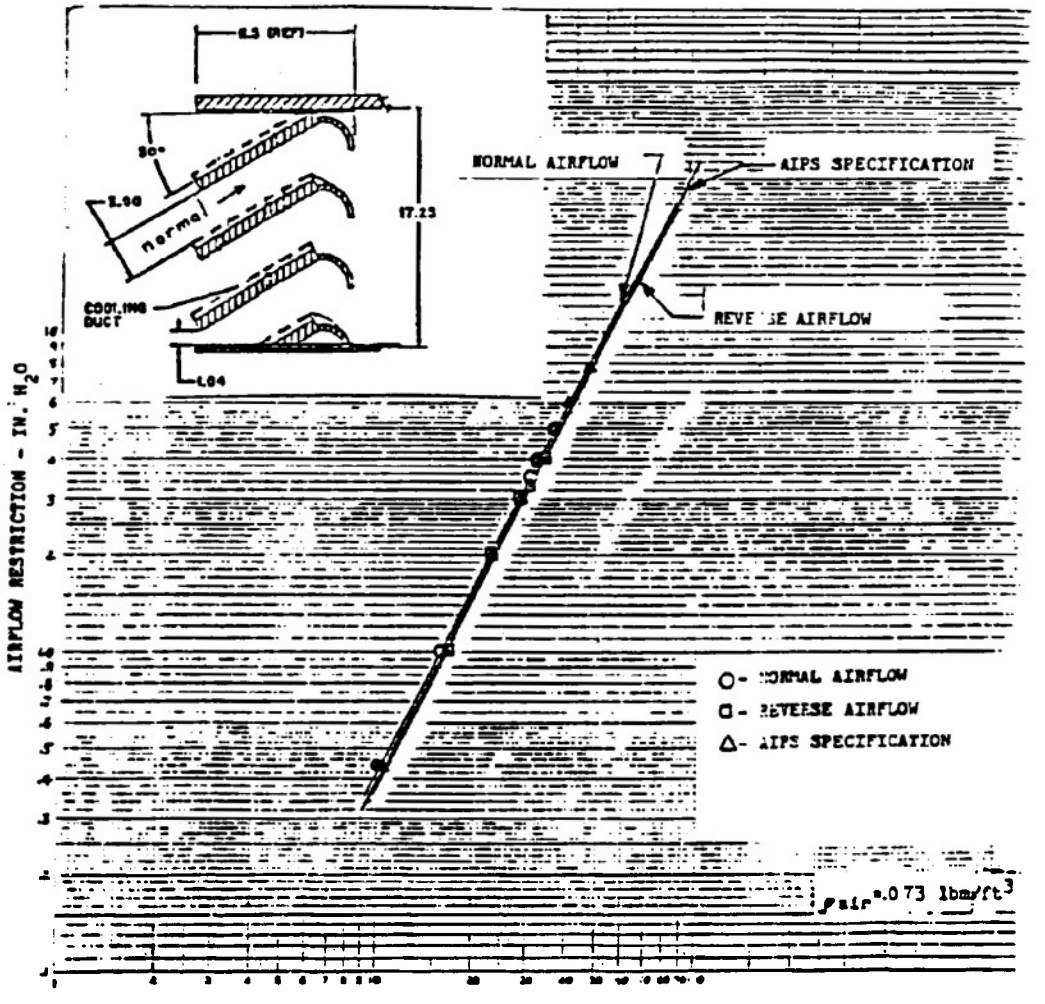


Figure 5-9. **Face Velocity vs. Airflow Restriction, Grille Code "B"**

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